High Speed Optical Transmitter and Receiver

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LONG-TERM GOAL

This proposal concerns component development for a novel hybrid lidar-radar system for underwater surveillance. Computer simulations and laboratory measurements of pulsed lidar revealed a 17 dB suppression of the water backscatter signal (clutter) and corresponding target contrast enhancement. Preliminary ocean experiments have confirmed the potential of pulsed lidar to be a superior detection mechanism for underwater surveillance. The next step in the evolution of this novel technique is the improvement of the key components of the measurement system: the microwave modulated pulsed laser sources and high speed, large area photodetectors. These components are novel and with minor modifications are applicable in communications and other areas of current interest.

SCIENTIFIC OBJECTIVES

The overall transmitter objective is to develop a novel optical transmitter operating in the microwave and millimeter wave range at high power levels. The components developed will operate in the 4 to 100 GHz range with at least 20% information bandwidth at optical power levels of 2W CW and in the kW range in the pulsed mode. The transmitter will have inherently low noise characteristics and high linearity, and will be efficiently integrated with the microwave and millimeter wave components. Finally, the transmitter system will be low cost and reliable.

The overall photodetector objective is the development of a large area, high speed photodetector that also exhibits gain. This new photodetector will exhibit a gain of greater than 10^3, noise figure less than 1.5 dB, and a bandwidth greater than 10 GHz, while maintaining a 10 mm or larger active area. The photodetector is a vacuum phototube consisting of a GaAsP photocathode for blue-green light sensitivity and a metal-semiconductor-metal (MSM) anode device that collects and amplifies the beam of high energy photoelectrons emitted from the photocathode.

APPROACH

Blue-green lidar (light detection and ranging) is used for underwater surveillance. A pulse of optical radiation is transmitted from an airborne platform and target information is extracted from the detected echo. Although lidar has the potential for replacing acoustic techniques for

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underwater remote sensing, attenuation, dispersion, backscatter clutter and lack of coherent signal processing limits the performance of lidar in the detection of underwater objects.

In response to these shortcomings, a detection scheme has been developed by combining the sophisticated detection and signal processing techniques of microwave radar and the underwater transmission capability of lidar. In the hybrid configuration the radar signal is impressed on the optical pulse by modulating the carrier at microwave frequencies. The reflected optical signal, with the superimposed microwave envelope, is detected by a high-speed photodetector. The radar subcarrier is then recovered by a microwave receiver and processed independently from the lidar return. In this technique, both the optical carrier (lidar) and the microwave envelope (radar) are examined simultaneously from a single measurement.

The optical transmitter for the hybrid lidar radar or communications is depicted in Fig. 1. It consists of a diode pumped, mode locked microchip laser, a diode pumped microchip resonant amplifier, a frequency doubler and diode pumped microchip Fabry-Perot modulator.

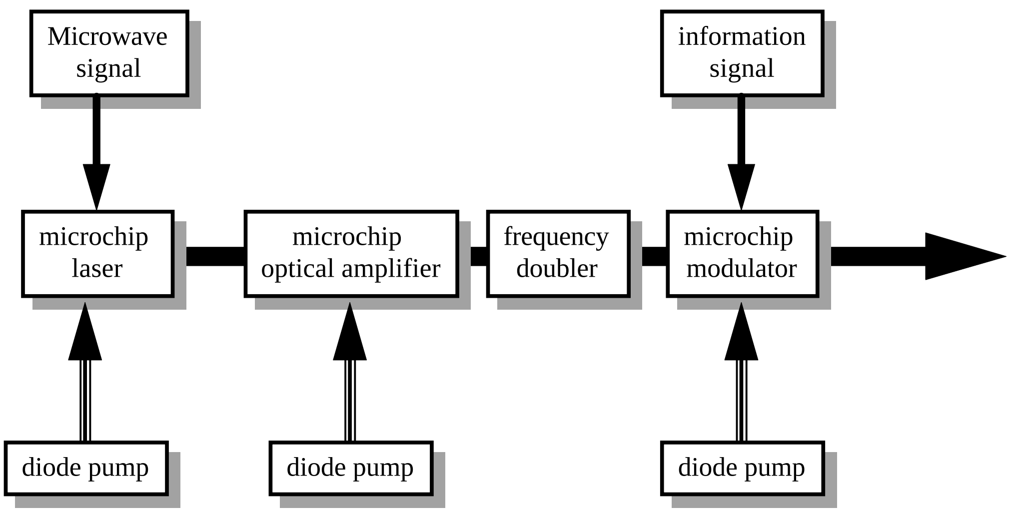

Fig. 1. Configuration of the optical transmitter with external modulator.

The photodetector in the optical receiver of the hybrid lidar radar system, depicted in Fig. 2, is an intensified photodiode (IPD) [1]. The currently available IPD uses a Schottky diode anode and this project involves the incorporation of a metal-semiconductor-metal (MSM) device as the anode in place of the Schottky diode to increase bandwidth while maintaining the large area and gain. The MSM device offers many advantages including bandwidths exceeding 100 GHz, low capacitance due to the interdigital electrode structure, low dark current, and ease and low cost of fabrication. The critical design parameters for the MSM diode are electrode width, spacing, and metal thickness and type. These parameters will be systematically varied in the design of the MSM. On the basis of this design, various geometry MSMs will be fabricated and tested in our laboratory. A very limited number of the best devices will then be incorporated into the IPD and evaluated.

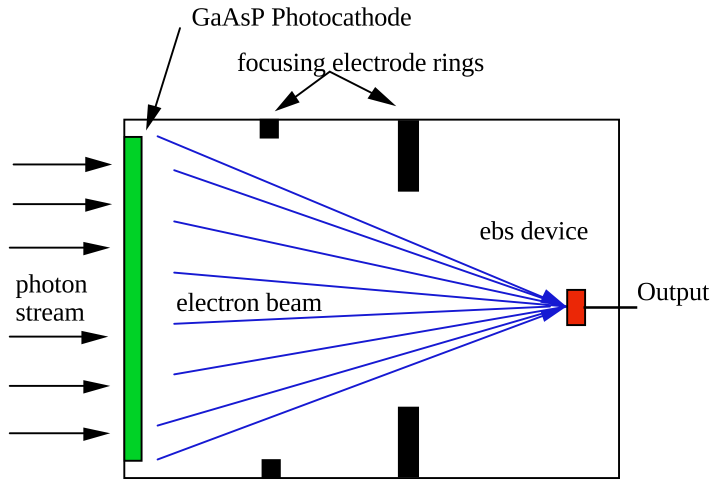

Fig. 2. Intensified photodiode structure.

WORK COMPLETED

Accomplishments for the design, fabrication and testing of the high speed optical transmitter include:

- Design completed for a $LiNOb_3$ microchip laser with Nd doping (λ =1.06 µm) for Lidar applications and an Er doped microchip laser (λ=1.6 µm) for communication systems.
- A prototype laser was fabricated and is currently being characterized.
- A microchip Fabry-Perot modulator has been designed, fabricated, and is currently being evaluated.

Accomplishments for the design, fabrication and testing of the large area, high speed optical receiver include:

- Completed design, fabrication, and testing of various geometry MSM devices on bulk GaAs with excellent measured dark and photoresponse performance.
- Analysis of the photocathode thickness versus quantum efficiency and bandwidth resulted in an optimum photocathode active layer thickness of 0.6 µm.
- Fabrication of a prototype photodetector, using an optimized 8 mm diameter GaAsP photocathode and 300 μm^2 MSM anode is in progress.

RESULTS

In this section the design and any experimental results will be presented for both the transmitter and photodetector.

The microchip laser uses a y-cut Lithium Niobate ($LiNbO_3$) crystal as host material, doped with 0.44-mole % of Neodymium (Nd). Lithium Niobate was selected for the laser because it has a large electrooptic coefficient, and therefore can effectively interact with the microwave field. Neodymium is added to the crystal to provide for lasing at 1.084µm wavelength. Dielectric mirrors were directly deposit on the crystal surfaces forming an optical cavity as shown in Fig. 3. The length of the laser cavity was designed to be 3.4mm, which also resonates at 20GHz, matching with the desired millimeter wave carrier for this particular experiment.

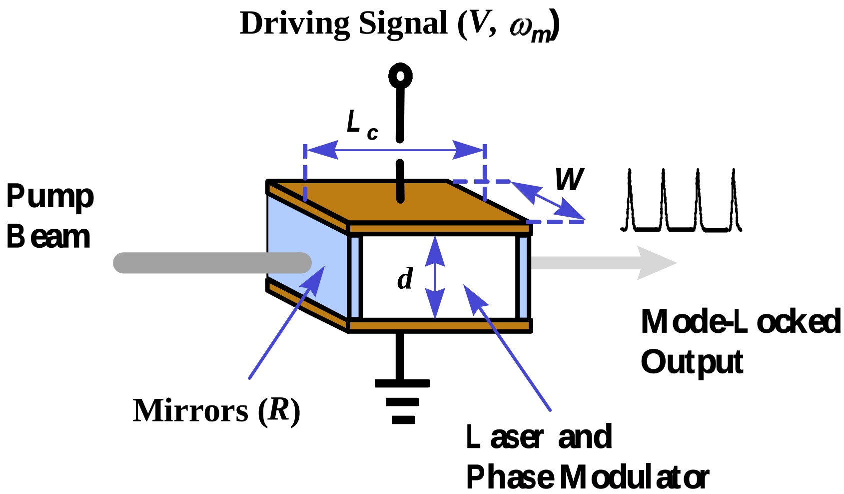

Fig. 3. Microchip laser structure.

The laser was mounted in the gap of a reentrant microwave cavity where the field is concentrated. The pump beam with a maximum output of 3W CW at 814nm wavelength was collimated and coupled to the Nd:$LiNbO_3$ laser using free-space optics. The highest optical output of 35mW was obtained for an estimated absorbed pump power of 200mW, indicating a conversion efficiency around 17.5%. Further evaluation in the optical and microwave domains is in progress.

The prototype Fabry-Perot modulator consists of a 1 mm long y-cut $LiNbO_3$ crystal having a 1 mm^2 cross section with 90% reflectivity mirrors directly deposited on the end faces of the device. The design called for the etalon to have mirror flatness of l/100, and a parallelism better than 1 arc second. The calculated finesse of the etalon is 29.8, and its capacitance is estimated to be 0.60 pF. With the lumped element configuration, shown in Fig. 6, a 50 % modulation depth, a bandwidth in excess of 4 GHz and driving voltages below 20 volts are predicted [2]. Characterization is in progress.

The MSM electrode dimensions were optimized using a novel two dimensional carrier transport model based on electron bombardment carrier generation. With an optimized 650 angstrom titanium electrode with 8 µm width and 4 µm gap spacing, an electron bombardment bandwidth of 3 GHz and optical bandwidth of 5 GHz are predicted for an MSM with a total detector area of 300 µm^2. The model predicts an electron gain of 1150 under bombardment of 8000 eV incident energy electrons. Due to the lack of a suitable electron bombardment test station, the fabricated MSM devices were tested optically to prove functionality. Excellent DC dark and photoresponse characteristics show a dark current of < 10 nA and responsivity of 0.3 A/W at a bias of 15 Volts. The optical time response of the MSM was measured using a Ti:Sapphire mode-locked laser with a 100 fs pulse width at a wavelength of 814 nm and FWHM values of 91, 87, and 94 ps for a bias level of 10 Volts, corresponding to a bandwidth of nearly 4 GHz.

To predict the performance improvement of the IPD using the MSM as the anode, the impact of the photocathode on performance must be evaluated since the overall response of the IPD depends on both the photocathode and the anode. The 8 mm diameter transmission mode photocathode exhibits quantum efficiencies greater than 40% and consists of a 0.6-1.0 μm $GaAs_{0.7}P_{0.3}$ active layer, a 500 angstrom AlGaAsP layer, and a Si_3N_4 quarter-wave anti-reflection coating optimized for peak transmission at 550 nm. The bandwidth of the photocathode depends on the active layer thickness. An optimal thickness of 0.6 μm provides the necessary bandwidth and responsivity.

Fabrication of a prototype IPD with a 0.6 μm photocathode and MSM anode is in progress.

IMPACT/APPLICATIONS

If further testing of the optical transmitter shows the expected results, we believe this technology will be found attractive to communication engineers, as they can be used in a number of different network architectures. In particular there is a growing interest in fiberoptic access to wireless communications in congested areas such as inner cities, office buildings and large ships. Particularly, the shipboard communication system provides for more mobility (wireless), higher bandwidth (optical fiber) and more security (mm-wave fading). Further development of the large area, high speed photodetector will open new possibilities for increased performance in the hybrid lidar-radar systems, as well as other areas including biomedical imaging, spectroscopy, as possibly free-spaced communications.

TRANSITIONS

There are no transitions to report.

RELATED PROJECTS

There are currently no related projects.

REFERENCES

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